Guest Commentary

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A New Alternative for Sizing Septic Systems

When a builder, a designer, and a regulator wonder how big the septic system for a house should be, they might approach the question from different points of view. The builder might wonder, "How big does it have to be to last through my warrantee period?" The designer might ask, "How much water are the people who are buying this house likely to use?" The regulator might ask, "If this house is filled to capacity with teenage obsessive-compulsive hand washers, how much water will they use?"

These points of view have fought it out in our political process and have shaped current environmental health laws. The result is that houses are not built with septic systems expected to last the life of the structure and much of the design criteria is based on water use averages (rather than worst-case scenarios), with a modest safety margin usually built in for unusual occupancy periods. What this essay will propose is a reasoned approach using statistics and measured data to design for water use flows. This approach will more evenly distribute public health risk and more fairly spread the financial burdens to builders across the different classes of single-family homes.

After years of regulatory evolution, most health jurisdictions size septic systems on the basis of 100–150 gallons per bedroom per day. Some builders, trying to minimize septic-system size so as to maximize house size on small lots, have adopted practices of building "dens," "bonus rooms," or "sewing rooms" that look suspiciously like bedrooms. This "three-bedroom mansion" phenomenon can be seen in any area where incomes are high and land is scarce.

The response of some regulators has been to require that any room that can be used as a bedroom be counted as a bedroom. This regulation is enforced regardless of the likelihood that these rooms will be used as bedrooms. The bedroom-definition dance has stirred up a great deal of frustration and animosity for builders and regulators alike. Just how important is quantifying the number of bedrooms to a good septic-system design?

The time has come to see if the linear-gallons-per-bedroom approach does an accurate job of predicting water use. We should, at the same time, find out if quantifying other physical aspects of houses will give us better water use predictions than does simply counting bedrooms. Below is a review of two studies done by Public Health–Seattle & King County and the Washington State Department of Health that can help answer these questions.

The Q1000 and H200 Studies

In the Q1000 Study, the assessor's property records for roughly 1,000 houses served by sewers were matched with water records from 1994 to 1996 (Figure 1). Winter water use was isolated for each house (to minimize the influence of outdoor water use), and peak two-month periods and overall two-year winter averages were established for each house. The assessor's records were used to establish the number of toilets and bedrooms, and the living-area square footage for each house.

Each of those three structural parameters was statistically correlated against the water averages. They were then run through multiple-regression analysis to establish the relative importance of each structural parameter in predicting water flows.

The H200 Study did essentially the same thing as the Q1000 Study, but it used 200 houses served by septic systems and used water use figures from 2000–2001. Both studies are summarized, and their methods and findings are available, in a report posted at http://dave.glen.home.att.net.

Study Findings

Does the Number of Bedrooms Correlate with Average Water Use?

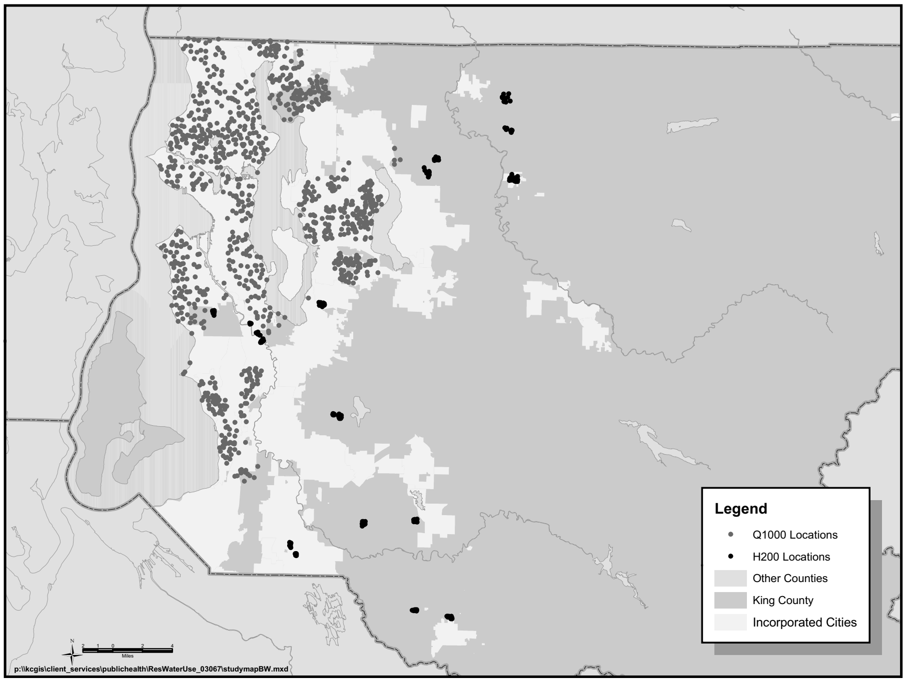
The simple answer is yes—but not very well.

A quick statistical review may be appropriate at this point. "Correlation" measures the tendency of one set of numbers to rise or fall in relation to another set of numbers. The R^2 is a value that represents the percentage change in one variable that is related to the change in another variable. A perfect correlation would result in an R^2 of 100 percent, while totally unrelated variables would have an R^2 of around zero. Table 1 gives the R^2 values found in the Q1000 and H200 studies.

As one can see, the R^2 values are not very impressive. They are, however, statistically significant to 99 percent, and even the small differences between variables for the Q1000 Study are real. The positive bedrooms-to-water-use correlations mean that one can expect the average three-bedroom house to use less water than the average four-bedroom house. What one cannot expect is to be able to assign a monolithic gallon-per-bedroom value that is very useful in predicting water flows. These R^2 values basically say that water use and the number of bedrooms are related, but that water use cannot be well predicted in a linear manner.

FIGURE 1

Q1000 and H200 Study Locations



Is There a Better Way of Predicting Flows?

In both studies, square footage was better correlated with water use than was the number of bedrooms. Furthermore, in the H200 Study, statistical regression analysis showed that square footage was the only statistically significant predictor.

Should We Abandon Bedrooms for Living-Area Square Footage?

This question is difficult to answer because of the great variation in the data within and between the studies (see Appendix B of the report at http://dave.glen.home.att.net). Unlike the H200 Study, the multiple-regression models for the Q1000 Study suggest that using bedrooms and square footage together will give higher correlations than either can provide alone. The contribution of toilets was not statistically significant to 95 percent in either of the multiple-regression models.

One road to improvement is to continue to size by number of bedrooms but to tie a house size limit to each bedroom design class. For instance, when bedroom design classes are defined in increments of 1,000 square feet, both studies show an improvement of correlation with water use over design classes based on number of bedrooms alone (Table 1). An example of this method is given under the heading Design Example at the end of the next section of this paper.

Suggested Course for Setting Septic Sizing Limits

1. Choose a Design Class on the Basis of Overall Correlations

Currently "number of bedrooms" is the most popular "design class." Both of the studies discussed here suggest that square footage should be considered when houses are assigned to a class. The Q1000 Study supported using the number of bedrooms in conjunction with square footage.

2. Get Local Data for Each Design Class

Pitkin County (Aspen), Colorado, conducted a similar water use study. Although that study also found that square footage had greater correlations with water use than number of bedrooms, the water use per class was considerably higher than in King County (see appendices A and D of the report at http://dave.glen.home.att.net). This difference indicates that, if possible, local data should be used. Many assessors' databases can now be accessed electronically, and many water districts can also provide billing information in compatible electronic form.

3. Choose an Acceptable Percentage of Compliance and Hold Each "Design Class" to It

If all septic systems were designed for the worst water user, there would not be enough land in the world to fit them on. Select a goal for compliance (75 percent ... 80 percent ... 90 percent) and design to it. Make sure that each design class meets the same compliance goal so that the economic burden to the builder is justified across the board.

4. Choose a "Safety Factor"

A two-year water-use average does not tell the true story about day-to-day flows from a house. The 1980 U.S. Environmental Protection Agency (U.S. EPA) onsite design manual states that for the vast majority of days, the flows from a house will be within 50–150 percent of the average water use of that house (p. 51). A 150 percent safety factor is often applied because of this statement. So, if one thinks a house will average 100 gallons per day and one chooses a 150 percent safety factor, the septic system should be designed for 150 gallons per day. (For more insights into safety factors, peak monthly flows, and peak daily flows, see Appendix C of the report at http://dave.glen.home.att.net.)

5. Design limits Should Be Based on the Specific Flows of Each Design Class, the Percentage of Desired Compliance, and the Safety Factor

If bedrooms are chosen as the design class and 75 percent compliance is desired, the average flows for the 75th percentile should be multiplied by the safety factor. Example: If the 75th percentile of four-bedroom houses averages 244 gallons per day, all four-bedroom houses should be designed for 244 × 1.5, or 366 gallons, per day.

6. Don't Be Too Conservative

It is important to keep the measured water use averages in perspective by keeping the following points in mind:

- Much of the data taken from existing houses is based on houses that are not equipped with water-saving fixtures. New construction, with mandatory low-flow fixtures, can be expected to entail less flow than identical structures without them. *It should be noted, however, that water flow reductions based on low-flow fixtures will probably result in higher-strength*

TABLE 1

R^2 for Winter-Water-Use Averages

Study Group (sample size)	Toilets	Bed-rooms	Square Feet Grouped in 10s	Square Feet Grouped in 1,000s	Combined Bedroom & 1,000 Square Feet	Combined Bedroom & 800 Square Feet
Q1000 Sewer (953)	6.6%	7.5%	7.8%	6.7%	8.0%	8.7%
H200 Septic (201)	15.5%	5.6%	24.6%	26.9%	18.9%	22.4%

TABLE 2

Bedroom Classes with 1,000-Square-Foot Limits Per Class

Class	Number of Houses in Sample	84th Percentile × 1.5 Is the Design Limit
1–2 bedrooms under 2,000 sq ft	184	330 gal/day
1–2 bedrooms over 1,999 sq ft but under 3,000 sq ft and 3 bedrooms under 3,000 sq ft	499	354 gal/day
1–3 bedrooms over 2,999 sq ft but under 4,000 sq ft and 4 bedrooms under 4,000 sq ft	332	429 gal/day
1–4 bedrooms over 3,999 sq ft but under 5,000 sq ft and 5 bedrooms under 5,000 sq ft	102	512 gal/day
1–5 bedrooms over 4,999 sq ft but under 6,000 sq ft and 6 bedrooms under 6,000 sq ft	31	584 gal/day

wastes entering drainfields. Design should take this likelihood into account.

- The water data will also include houses with people who use outdoor water in the winter. This circumstance means that the house that appears to be in the 75th percentile of indoor water users will actually be in a higher percentile.
- The Q1000 and H200 studies found that only 14 percent of houses had a peak two-month period that averaged more than 150 percent of their overall winter average. This finding implies that, for the vast majority of houses, septic systems with timed dosing and surge tanks can be used to keep daily flow within design limits even during high-use periods.
- Although high water use is associated with premature septic-system failures, it does not necessarily equate with a failure. Some septic systems are quite resilient to stress periods.

Design Example

This example uses bedrooms as the design class but with a 1,000-square-foot limit per class. The parameters include a desired 84 percent compliance rate and a 150 percent safety factor. Table 2 shows the design limits suggested by the actual water use averages from the combined *H200* and *Q1000* and the above parameters.

Conclusion

The insights garnered from the King County studies indicate that it is time for the design community to look at real water use figures for different classes of houses when deciding septic-system size. With statistically defensible design classes, reasonably selected compliance percentages, and justifiable "safety factors," we can retire the inaccurate and unfair standard of 100–150 gallons per bedroom, and look at houses holistically and in context with measured expectations.

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